



AIR FORCE RESEARCH LABORATORY



GPS Support to the MWA Low Frequency Demonstrator

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THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER



AFRL-Supplied GPS Receivers

Three Novatel (GSV) 4004B Ionospheric Scintillation and TEC Monitors



GSV 4004B GPS IONOSPHERIC SCINTILLATION AND TEC MONITOR WITH ANTENNA OPTIONS

- Uses selected low-noise ovenized oscillator for superior low-jitter phase measurements
- Record raw 50 Hz I/Q data (L1 only) or lower cadence (1-sec, 10-sec, 30-sec) processed parameters (TEC, carrier phase, code, etc.)
- Not set-up for differential use, but will accept external oscillator
- Unit provides essentially no visible feedback that it is operating properly
- Mated with 20-m LMR-400 cable (3.5 dB loss; up to 10 dB acceptable)

Current Real-Time GPS Display

GPS Data Collection System

Ver 1.18, AFRL/Radex Inc.

21:06:40 UTC 10/06/2003

Ashtech uZ	Lat	Lon	Alt	PDOP
	42.481995	-71.263843	22.057000	3.4

TRACKING

PRN	01	02	03	13	15	16	31
AZM	208	063	084	245	076	070	194
ELV	35	55	71	45	21	28	60
SCA	45.0	56.3	54.6	42.8	42.3	48.1	52.4
SP1	44.6	53.8	52.5	44.0	37.7	47.7	52.0
SP2	40.1	49.5	47.8	35.9	32.4	42.8	47.4

STATISTICS(31s)

PRN	01	02	03	13	15	16	31
NUM	601	601	601	601	601	601	601
1S4	0.10	0.12	0.04	0.20	0.22	0.08	0.05
2S4	0.05	0.07	0.02	0.04	0.03	0.04	0.01
TEC	77	57	48	61	93	53	53

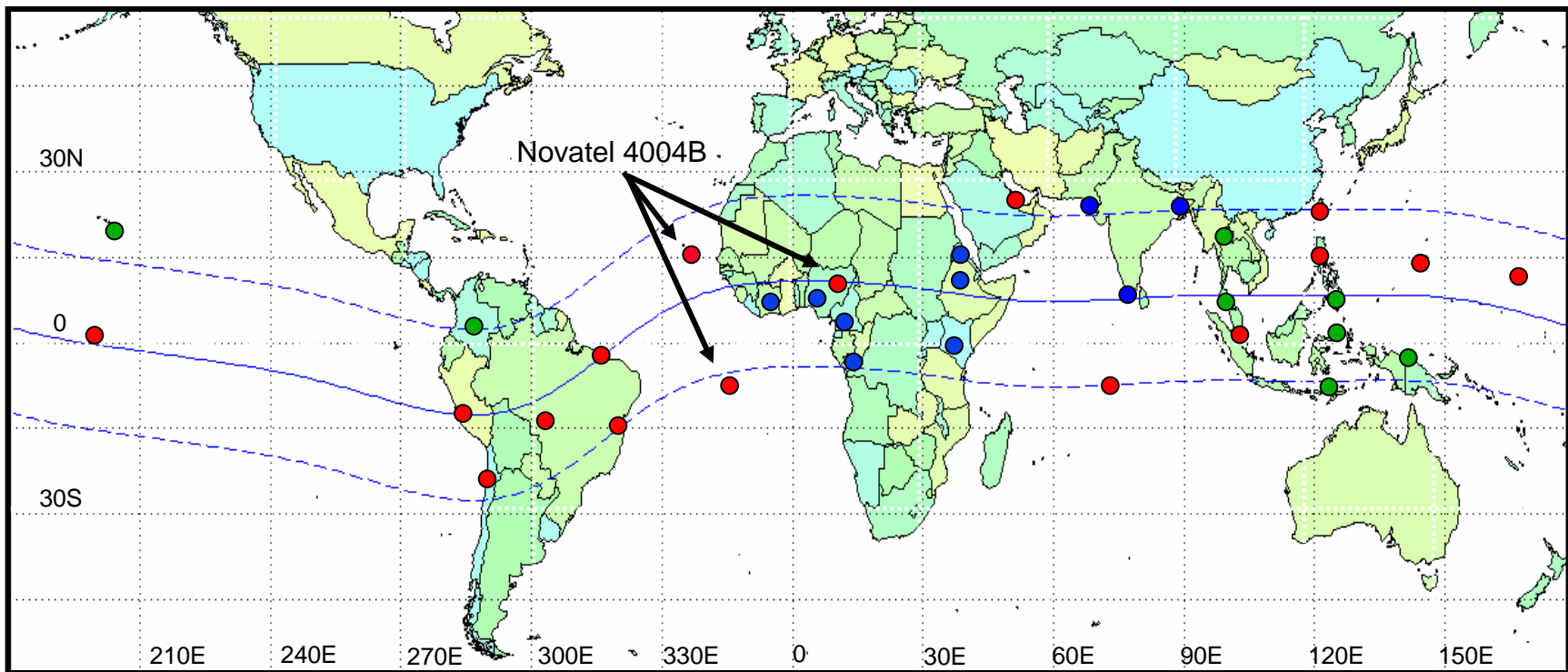
OUTPUT: data/031006_210436.uz

STATUS: Normal

RECORDS (g/b): 2117/ 3 LOST BYTES: 0

SCINDA Ground Stations

Present and anticipated thru 2008*



● Existing Sites

● UN IHY Sites

● Other/collaboration

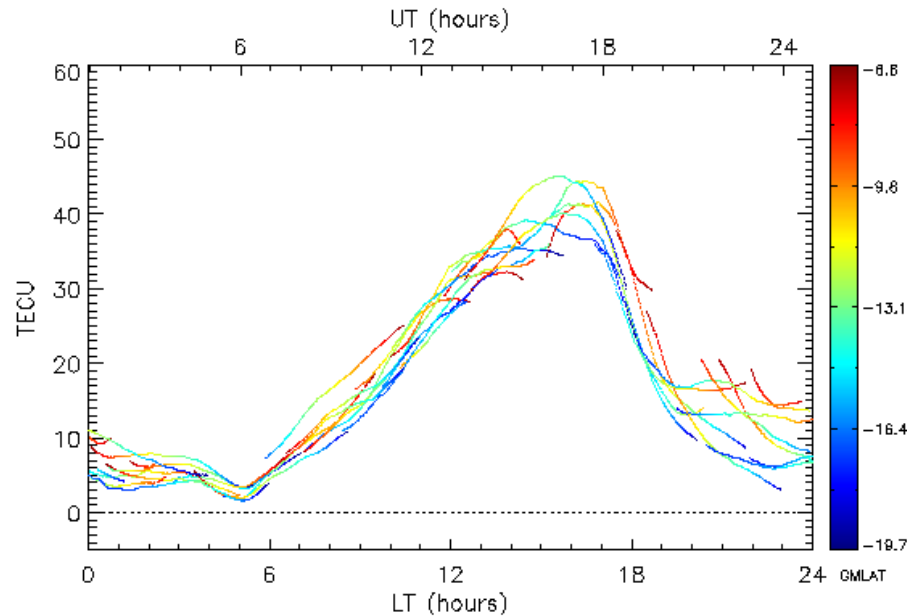
*Future sites shown represent approximate desired locations; actual sites TBD

TEC from Ascension & Kwajalein

Halloween 2006

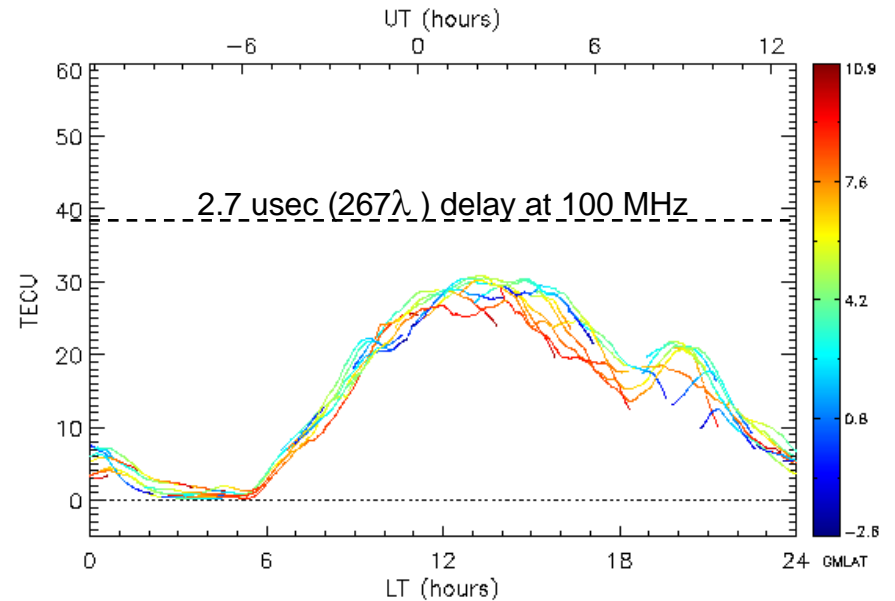
Calibrated TEC

Ascension Island, 10/31/2006



Calibrated TEC

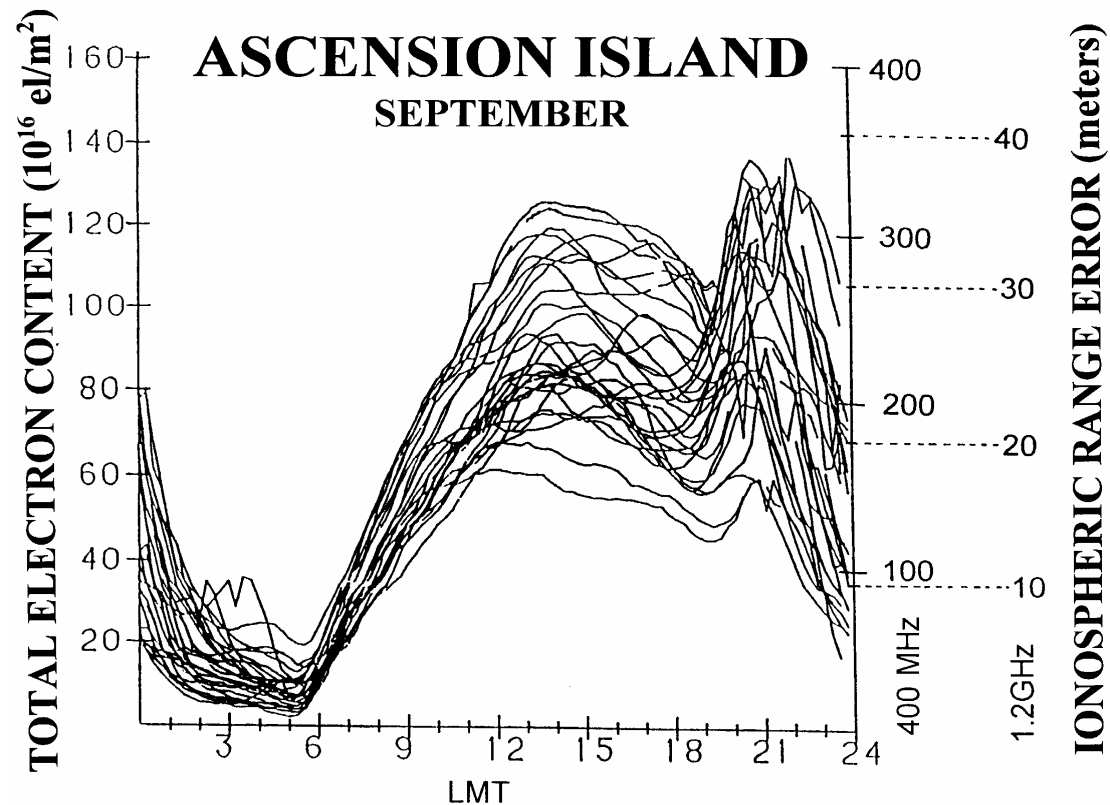
Kwajalein, 10/31/2006



- Receiver bias calibration performed using data from 03-06 LT when gradients are minimum
- Technique optimal for mid-latitude sites, but absolute values will still be no better than ~1+ TEC unit

Group Delay as a function of TEC

Daily Variation of TEC



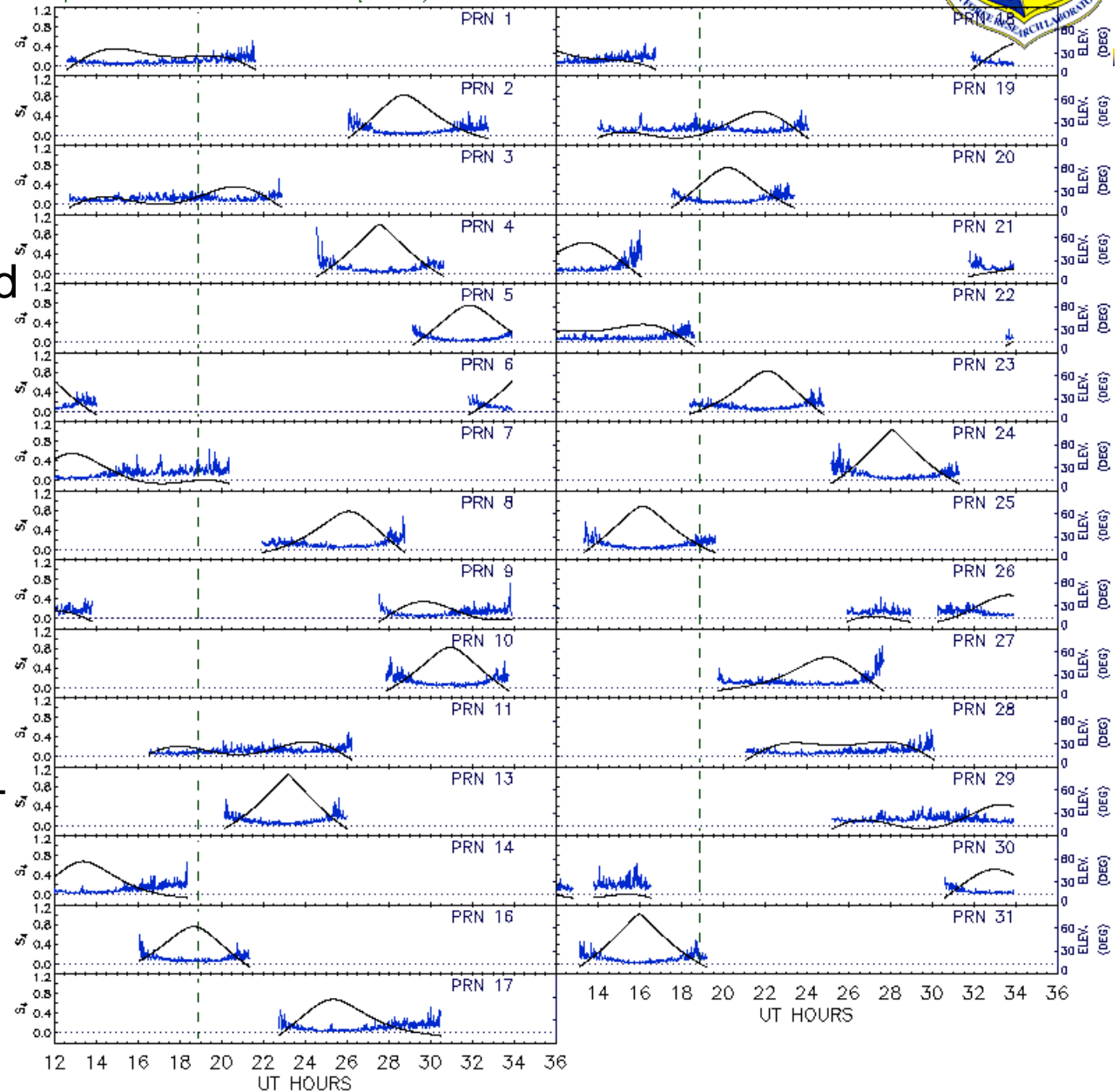
- 100% day-to-day variation at equatorial latitudes
- Delay increase by X3 for low elevation angles (long slant paths)

GPS S_4 & Elevation Angle Evening of 10/31/2006 : Ascension Island



Updated 01 Nov 10:42Z : Local Sunset (300 Km) at 18:51UT

- Novatel Pinwheel antenna maintains good sensitivity at low elevation angles
 - Vulnerable to multipath effects in “non-pristine” environment
- MWA site topography ideal for GPS
 - Care should be taken in installation (ground-plane, etc.)



Ionospheric Dielectric Properties

Nominal dielectric permittivity in “smooth” ionosphere

$$\langle \varepsilon \rangle = \left(1 - \frac{f_p^2}{f^2} \right) \varepsilon_o \quad f_p^2 = \frac{e^2 N}{m_e \varepsilon_o}$$

Linearized description when weak density fluctuations are present

$$\varepsilon = \langle \varepsilon \rangle (1 + \varepsilon_1(r, t)) = \varepsilon_o \left[\left(1 - \frac{f_p^2}{f^2} \right) + \left(\frac{f_p^2}{f^2} \right) \frac{\Delta N}{N} \right]$$

Permittivity has a direct dependence on total ΔN

- “Roughness” of mid-latitude ionosphere has never been carefully studied (standard techniques insensitive to irregularities except during storm-induced activity)
- MWA has sensitivity to perform routine measurements

Summary

- GPS sensors will provide good estimates of ionospheric TEC at MWA
 - May want to consider operating receivers with common external oscillator signal to guarantee “coherent” GPS measurements across aperture
- Unprecedented mid-latitude ionospheric structure studies possible with MWA
 - Relevant for proposed space-based UHF/VHF coherent synthetic aperture radar (SAR) systems